Reciprocating Electric Compressor

Field of the Invention

The present invention relates to reciprocating electric compressors to be used in refrigerating-cycle devices such as a refrigerator having a freezer, a vending machine, and an air-conditioner.

Background of the Invention

A reciprocating electric compressor (hereinafter simply referred to as "compressor") employed in refrigerating-cycle devices such as a refrigerator with a freezer, a vending machine, and an air-conditioner has been required to be highly efficient and reliable. In general, a conventional compressor is equipped with a crankshaft incorporating a lubricator, and a typical one is disclosed in Japanese Patent Publication No. S62 – 44108. The conventional compressor is described hereinafter with reference to Fig. 8.

Fig. 8 is a sectional view of the conventional compressor. Compressor 1 is housed in enclosed container 2, which accommodates frame 3 in the middle, motor unit 4 at a lower section, compressing mechanism 5 at an upper section. Crankshaft 7 extends through bearing 6 of frame 3. On an outer wall of crankshaft 7, rotor 8 of motor unit 4 is rigidly mounted. Crankshaft 7 has main shaft 70 and eccentric shaft 9, and engages with slider 11 of piston 10 via eccentric shat 9. Piston 10 is one of elements of compressing mechanism 5.

Slant hole 12 (hereinafter referred to simply as "hole") slantingly extends from the bottom of crankshaft 7 to the lower end of bearing 6 through crankshaft 7, and opens onto the outer wall of shaft 7. Hole 12 has a rather small diameter.

A part of crankshaft 7 rests within bearing 6, and on this resting section,

spiral pump 14 (hereinafter referred to simply as "pump") is formed. Pump 14 comprises a single leading groove which communicates with lateral hole 13 at its lower end and vertical hole 15 formed in eccentric shaft 9 at its upper end. Vertical hole 15 opens into inner space of container 2 at its upper end, and communicates with the slid face of thrust-bearing 16 at its lower end. Lubricant oil 17 is pooled in the lower section of container 2, and crankshaft 7 dips therein at its lower end.

An operation of the foregoing conventional reciprocating compressor is described hereinafter. When motor unit 4 is turn on, rotor 8 starts spinning, which entails crankshaft 7 to rotate. Rotation of crankshaft 7 reciprocates piston 10 engaging with eccentric shaft 9 via slider 11, so that compression is carried out. Lubricant oil 17 rises from the lower end of crankshaft 7 through hole 12 extending slantingly upward due to centrifugal force, and moves upward via lateral hole 13 to pump 14 of a main shaft 70, which then transmits lubricant oil 17 to bearing 16 and eccentric shaft 9, and then lubricant oil 17 is discharged into the space within container 2.

As such, lubricant oil 17 rises through hole 12 that extends slantingly and upward from the lower end of shaft 7 due to centrifugal force, and pump 14 formed of the one-way leading groove from lateral hole 13 transfers lubricant oil 17 to the slid section of bearing 16, where lubricant oil 17 performs lubricating action. A winding direction of the leading groove is determined on the premise that pump 14 operates in a given rotating direction. Therefore, if pump 14 operates in a reverse direction to the given one, down-force works in pump 14, so that no lubricant oil is supplied to the upper section of bearing 6. As a result, bearing 6 incurs abnormal abrasion, which causes a breakdown. For instance, in the case of a reciprocating compressor which employs a three-phase induction motor as the motor unit, it can be inversely rotated due to a wrong wiring.

Thus a plugging relay needs to be integrated into the circuit for preventing the breakdown due to the reversal rotation; however, since the relay is so expensive that the cost of the compressor is obliged to increase.

There is another conventional reciprocating compressor which employs a single-phase and resistant-start induction motor using a PTC relay as a starter. In this compressor, when an instantaneous power interruption occurs, which does not give a recovery time to the PTC relay, the piston is pushed back due to the pressure of a compressed room. If the power is recovered during this reversal rotation, the compressor is kept rotating inversely. In this case, the lubricator does not work properly, and the slid section incurs a breakdown due to abrasion.

In order to overcome the problems discussed above, a reciprocating compressor equipped with both-way leading grooves has been proposed. This structure allows reversible operation; however, there is still no reciprocating compressor operable in both rotating directions and equipped with a compressing unit, which needs high pump-head for lubrication, over a motor unit.

Summary of the Invention

The present invention provides a reciprocating compressor equipped with a compressing unit over a motor unit. Rotation of the motor unit is converted into reciprocation of a piston by a crankshaft. The crankshaft includes (a) a centrifugal pump disposed in a lower section, and (b) a pair of spiral pumps being functionally independent and having two leading grooves which communicate with the centrifugal pump and run in an opposite direction to each other. The crankshaft opens into an enclosed container at its upper end, and has a pair of eccentric paths (vertical holes) communicating with the spiral

pumps respectively and being functionally independent.

Brief Description of the Drawings

Fig. 1 shows a sectional view of a reciprocating compressor in accordance with a first exemplary embodiment of the present invention.

Fig. 2 shows an enlarged view of a crankshaft of the compressor in accordance with the first exemplary embodiment of the present invention.

Fig. 3 shows an enlarged view of a conventional crankshaft similar to that of the compressor in accordance with the first exemplary embodiment of the present invention.

Fig. 4 shows a comparison about amounts of discharged lubricant oil between the compressor used in the first embodiment and a compressor similar to the one used in the first embodiment.

Fig. 5 shows a sectional view of a reciprocating compressor in accordance with a second exemplary embodiment of the present invention.

Fig. 6 is a circuit diagram of the compressor in accordance with the second exemplary embodiment of the present invention.

Fig. 7 illustrates an operation of the compressor in accordance with the second exemplary embodiment of the present invention.

Fig. 8 shows a sectional view of a conventional reciprocating compressor.

Detailed Description of the Invention

Exemplary Embodiment 1

Fig. 1 shows a sectional view of a reciprocating compressor in accordance with the first exemplary embodiment of the present invention. Fig. 2 shows an enlarged view of a crankshaft of the compressor shown in Fig. 1.

Enclosed container 18 accommodates motor unit 21 comprising stator 19

and rotor 20, and compressing unit 22 driven by motor unit 21. Container 18 pools lubricant oil 23 at its lower section. Motor unit 21 is a three-phase induction motor which allows the compressor, powered by a three-phase power supply, to rotate in both directions regardless of a wiring direction.

Compressing unit 22 is detailed now. Crankshaft 24 includes eccentric shaft 25, sub-shaft section 26 and main shaft section 27. Sub-shaft section 26 and main shaft section 27 sandwich eccentric shaft 25 vertically in a concentric manner. Cylinder block 29 includes compressing room 28, sub-bearing 30 and main-bearing 31. Both of bearings 30 and 31 cross with an axis of compressing room 28 at approx. right angles, and support sub-shaft section 26 and main-shaft section 27 respectively. Sub-bearing 30 can be disposed independently of cylinder block 29 and can be rigidly mounted to block 29. This structure achieves high pump-head for lubrication and rotation in both directions.

Compressing room 28 is equipped with piston 32 in a manner that piston 32 can be slidable, and piston-pin 33 press-fit into piston 32 is linked to eccentric shaft 25 with a linking section, namely, connecting rod 34. Valve-plate 35 includes an inlet valve and an exhaust valve (both are not shown), and is sandwiched by cylinder head 36 having an exhaust room (not shown) therein and cylinder block 29. Suction muffler 37 having an inlet (not shown) is sandwiched by cylinder head 36 and valve plate 35.

Main-shaft section 27 of crankshaft 24 has bottom hole 38 at its lower end. Cap 41 has throttle section 40 at its lower end and is press-fit into main-shaft section 27. Sucking hole 39 is prepared at the center of throttle section 40. In main-shaft section 27, slant path 42 extends slantingly and upward from bottom hole 38 such that the center of throttle section 40 is included within the inner wall of path 42, which forms a hollow cylinder. Path 42 is placed such that its upper end reaches a lower section of main bearing 31 and approaches the outer

wall of crankshaft 24.

Main-shaft section 27 is engraved spiral pumps 43A, 43B on its outer wall. Each pump has a leading groove running counter to each other and forms a helical groove. Pumps 43A and 43B communicate with slant path 42 at communicating section 44 provided at a lower section of the main shaft. Other sections than communicating section 44 are disposed such that they are independent of each other and free from crossing with each other.

A pair of eccentric paths 45A, 45B stand vertically inside eccentric shaft 25 and sub-shaft section 26 independently of each other. Those two paths form vertical holes and communicate with an upper end of pumps 43A, 43B respectively at communicating sections 46A, 46B prepared in an upper section of the main shaft. Upper ends of paths 45A, 45B open on an upper end of sub-shaft section 26 and communicate with the inside of container 18. Sub-shaft section 26 is engraved a pair of spiral pumps 48A, 48B on its outer wall, and those pumps form helical grooves communicating with each other via sub-shaft communicating sections 47A, 47B and paths 45A, 45B. Slant path 42 has vent hole 49 at its end, and vent path 42 communicates with the inside of container 18 and opens onto the upper end of main-shaft section 27. Thrust bearing 50 is rigidly mounted to an end of sub-shaft section 26, and forms a thrust bearing together with sub-bearing 30.

An operation of the foregoing reciprocating compressor is demonstrated hereinafter. When stator 19 of motor unit 21 is powered, rotor 20 starts spinning. In this embodiment, rotor 20 spins along rotating direction 51 viewed down from a top of the compressor.

Rotation of crankshaft 24 entails eccentric shaft 25 to move eccentrically, which reciprocates piston 32 in compressing room 28 via connecting rod 34 and piston-pin 33. Refrigerant is sucked into room 28 via the inlet of sucking

muffler 37, and compressed. The refrigerant passes through the exhaust valve, cylinder head 36, the exhaust room, and is finally discharged to a refrigerating cycle (not shown) outside container 18.

Next, the lubricating operation is demonstrated. Rotation of crankshaft 24 forces lubricant oil 23 to flow into cap 41 via sucking hole 39. Lubricant oil 23 then forms parabolic free-surface in cap 41 due to centrifugal force and counter force to the gravity generated in throttle section 40, and flows to slant path 42 via bottom hole 38.

Since path 42 extends slantingly and upward from bottom hole 38 to form a centrifugal pump, lubricant oil 23 further rises to communicating section 44 due to this centrifugal force. As such, crankshaft 24 includes the centrifugal pump formed of the following two elements: (a) slant path 42 extending upward from the lower end of crankshaft 42 with its axis slanting toward the outer rim of crankshaft 24, and (b) throttle section 40 leading to lubricant oil 23. Thus lubricant oil 23 on the lower end of crankshaft 24 surrounded by throttle section 40 is subject to the centrifugal force due to the rotation of crankshaft 24. Throttle section 40 receives the downward force generated by the centrifugal force, thereby increasing upward force. Further, the slant of path 42 efficiently increases the pump head of lubricant oil 23. As a result, lubricant oil 23 can be transferred by the greater force regardless of rotating directions.

Since eccentric shaft 25 rotates in direction 51 viewed down from a top of the compressor, lubricant oil 23 flows into pump 43A from communicating section 44. At this time, lubricant oil 23 will not flow into pump 43B because downward force works and prevents lubricant oil 23 from flowing into pump 43B.

Pump 43A pushes lubricant oil 23 to rise, so that lubricant oil 23 further gains its pump head in path 45A via communicating section 46A, then finally

discharges and scatters from an upper opening of sub-shaft section 26.

Parts of lubricant oil 23 is supplied to eccentric shaft 25 on the way of passing through path 45A, and supplied to sub-shaft section 26 via communicating section 47A. Parts of lubricant oil 23 is also supplied to thrust bearing 50 via pump 48A, so that respective sliding sections such as main-shaft section 27, sub-shaft section 26 and eccentric shaft 25 are lubricated.

When rotor 20 rotates counter to rotating direction 51, lubricant oil 23 flows into pump 43B via communicating section 44, and is pushed by pump 43B upward, so that lubricant oil 23 passes through path 45B via communicating section 46B and gains its pump head in path 45B, then finally discharges and scatters from the opening at the upper end of sub-shaft section 26. Lubricant oil 23 is supplied to sub-shaft section 26 via communicating section 47B, and also supplied to thrust bearing 50 from pump 48B.

Lubricant oil 23 lifted by the centrifugal pump can be thus supplied to the respective sliding sections regardless of the rotating directions which can be changed by a wiring of the three-phase power supply. As a result, the reciprocating compressor, of which compressing unit is disposed at its upper section, compatible with both the rotating directions, is obtainable.

Slant path 42 has hole 49 at its top end, and hole 49 opens onto the upper end of main-shaft section 27 to communicate with the inside of enclosed container 18. This structure allows refrigerant gas generated from lubricant oil 23 to discharge into container 18 via hole 49. As such, the refrigerant gas of lubricant oil 23 existing in the lubricating route of crankshaft 24 can be exhausted, so that obstruction to the lubrication due to gas is reduced. A larger height between the lubricant oil surface in slant path 42 and the opening of hole 49 can prevent lubricant oil 23 from flowing out from hole 49, and this structure allows relatively increasing a pumping-up amount of lubricant oil 23, thereby

preparing a sufficient amount of lubricant oil.

Meanwhile, a conventional lubricating mechanism similar to this first embodiment is compared with the foregoing operation. Fig. 3 is an enlarged view of a conventional crankshaft similar to that of the first embodiment. This similar one has the following two different points: (a) This similar crankshaft is engraved leading grooves of bilateral directions such that spiral pumps 43C and 43D of the main shaft share their outlet. (b) There is one communicating section 46C of the main shaft and there is one eccentric path 45C.

Since pump 43C and 43D generate pressure to transfer the lubricant oil upward, this similar structure, in which the lubricant oil rises through a single line, i.e., 46C–45C, can be designed as a matter of course. This similar structure, however, discharges substantially less amount of lubricant oil from the top end of crankshaft 24. Fig. 4 shows the comparison between this similar structure and the structure of the first embodiment, namely, the amounts of lubricant oil supplied to both the structures per minute at 50 Hz and 60 Hz of power-supply frequency are compared. The result tells that the structure of the first embodiment can supply much more lubricant oil than the similar structure at both the frequencies.

In this similar structure, leading grooves of bilateral directions communicate with each other at communicating section 46C, so that a closed loop is formed such that parts of lubricant oil 23 drawn-up through a leading groove running along the rotating direction is restored toward the centrifugal pump through a leading groove running counter to the rotating direction. As a result, lubricant oil 23 supplied to eccentric path 45C decreases.

As discussed above, the first embodiment provides a pair of pumps 43A, 43B and a pair of slant paths 45A, 45B, and those pairs form functionally independent systems. This structure allows any pumps active with respect to

the rotating direction to transfer lubricant oil 23 upward free from interference from the lubricating paths regardless of rotating directions of crankshaft 24. Thus the pressure for transferring the lubricant oil is not weakened.

Moreover, sub-shaft section 26 is engraved a pair of pumps (helical grooves) 48A, 48B on its outer wall. Pumps 48A, 48B are functionally independent. The pumps are communicated with each other via communicating sections 47A, 47B and paths 45A, 45B. This structure allows sub-bearing 30 to keep holding the lubricant oil regardless of rotating directions.

Exemplary Embodiment 2

Fig. 5 shows a sectional view of a reciprocating compressor in accordance with the second exemplary embodiment of the present invention. Fig. 6 is a circuit diagram of the compressor, and Fig. 7 illustrates an operation of the compressor. The same elements as those in the first embodiment have the same reference marks, and the descriptions thereof are omitted here.

The second embodiment employs a motor unit different from that used in the first embodiment. Motor unit 21A is a single-phase resistant-start induction motor comprising rotor 52 and stator 53. As shown in Fig. 6, in stator 53, main coil 54 and starter coil 55 are coupled with each other in parallel, and PTC relay 56 is coupled with starter coil 55 in series as a starter.

An operation of the foregoing reciprocating compressor is demonstrated hereinafter. Upon energization, starter coil 55 is energized with the resistance of an element of PTC relay 56, and starting torque occurs in a given rotating direction for starting the operation. The element of PTC relay 56 sharply increases its resistance in one second after the start due to self-heating. Starter coil 55 is thus interrupted, and the current runs through only main coil 54 to keep the compressor operating. When the operation is halted, starter coil

55 needs to be energized for re-starting the operation. For that purpose, the element of PTC relay 56 needs cooling time 57 for reducing the resistance. If the cooling time is too short, the element of PTC relay 56 still remains in high-resistance state, and starter coil 55 cannot be energized, so that the compressor does not start.

In such a case, i.e., when the starter torque does not occur, if some external force is applied and it works as the starter torque, rotor 52 rotates along the direction of the external force. To be more specific, as shown in Fig. 7, instantaneous power interruption 58 shorter than one second happens. For instance, if piston 32 stops at a timing of just before the top dead center, piston 32 is pushed back by the pressure in compressing room 28, so that inverse rotation 59 occurs. During this inverse rotation, if energization 60 is restored, operation 61 is maintained with the inverse rotation kept going.

However, as described in the first embodiment, the reciprocating compressor in accordance with present embodiment can achieve steady lubrication regardless of the rotating directions. Therefore, if the compressor falls into an abnormal operation as discussed above, it never incurs a breakdown due to abrasion, so that the compressor is proved highly reliable.

The foregoing discussion proves that the present invention can achieve steady lubrication regardless of the rotating directions, and provide a reliable compressor.